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ABSTRACT

To make training cost-effective for its small systems customers, Digital Equipment Corporation (DEC) is providing self-instructional packages that can be used by customers on-site for training people to run their systems. To control the quality of this training, Computer Managed Instruction (CMI) is now incorporated into some of these packages. This CMI component uses a sequential probability algorithm that allows tests to vary in length depending upon the learner's skill level. This algorithm assures that the test results are statistically reliable while keeping the length of the tests as short as possible. All of the programs that make up this CMI system are written in BASIC; all of the CMI programs and data files for about 800 tests items will fit on a single, dual-density diskette. These characteristics make the CMI system applicable to internal and large systems training as well as small systems training, because it is small enough to fit on a diskette yet sophisticated enough to handle more and larger item banks if additional disk space is available. (Author/VT)

THE USE OF COMPUTER-MANAGED INSTRUCTION TO CONTROL ON-SITE, SELF-INSTRUCTIONAL TRAINING IN A SMALL SYSTEMS CUSTOMER ENVIRONMENT

by

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SUMMARY

The cost of small computer systems is constantly decreasing, but the cost of training people to run these systems is constantly increasing. To make training cost-effective for its small systems customers, Digital Equipment Corporation has been providing self-instructional packages for several years that can be used by our customers on-site. To control the quality of this training, Digital is now incorporating Computer-Managed Instruction (CMI) into some of these packages. This CMI component uses a sequential probability algorithm that allows tests to vary in length depending upon the learner's skill level. This algorithm assures that the tests results are statistically reliable while keeping the length of the tests as short as possible.

SMALL SYSTEMS CMI
Jesse M. Heines

CUSTOMER TRAINING AT DIGITAL

Digital offered its first customer training courses in lecture format in the basement of its legendary "mill" in 1962. Today, Digital's Educational Services Department offers over 100 lecture and self-instructional customer courses that are available in six regional training centers in the United States and eleven centers in other parts of the globe.

In 1975, Digital began to market very small, turn-key systems. The costs of these small systems are so low that even with our regional training centers it is often not financially feasible for customers to send their employees to Digital for training.

To make cost-effective training available to these customers, we have developed a new form of training called "tutorial documentation". This documentation is designed specifically for teaching completely inexperienced users to operate their systems without having a Digital instructor present.

Traditional customer education at Digital continues to grow with the sales of our medium- and large-scale systems, and tutorial documentation has now added a new dimension to the training services that we can offer our small systems customers. We have found, however, that the use of tutorial documentation at customer sites presents two new problems of its own:

- it is difficult to control the use of these materials when they are used on customer sites as well as we can when they are used in Digital facilities, and

- it is difficult to get accurate feedback on the strengths and weaknesses of these materials from our customers.

Digital's Tutorial Documentation Group is addressing these problems by writing computer-managed instructional materials to run on some of these small systems. These CMI materials use the customers' computers themselves to control their learning and collect data that we can use to assess the effectiveness of the tutorial documentation.

The remainder of this paper describes an existing computer-managed instruction program that is coupled with the tutorial documentation for one of Digital's new small systems.

CMI IN A CUSTOMER ENVIRONMENT

Interaction with Tutorial Documentation

Digital's tutorial documentation is written in a modularized format. The modules are arranged in a hierarchy, based on the prerequisite relationships of their objectives. Each module contains a list of its objectives, text and diagrams to help learners master these objectives, and exercises to be performed both in the workbook and on-line. The test item banks for the module tests are all stored on-line.

Before learners begin work on the tutorial documentation, they take the pretest for the first module (see Figure 1). If they can demonstrate mastery on this test, they are branched to the pretest for the next module in the hierarchy. This loop continues until the learners come to a test on which they cannot demonstrate mastery. At this point, they are directed to study that module off-line, and return to the CMI system when they are ready for the posttest.

An important quality of the CMI approach is that it gets users on-line as soon as possible and therefore has a definite Hawthorne Effect. In the past, customers often just skipped the tests that were included in our training packages, because they felt -- erroneously -- that testing benefits only the teacher. It is difficult, if not impossible, to change this feeling, but we can capitalize on the Hawthorne Effect to get more of our customers to take the tests. The directions for booting the system and running the CMI registration program are provided in the tutorial documentation in cookbook terms, so that even the most inexperienced of our users can get the CMI system on the air.

General Characteristics

The CMI registration program allows users to register themselves interactively. It records their first and last names (making sure that each is unique), and their addresses. This program also allows users to view the status of their work on each of the modules in the course.

The CMI test administration program presents true/false and multiple choice items (with either four or five alternatives) to users on a CRT terminal. These tests are generated interactively in real time. The items are randomly selected from item banks that are categorized by module and objective. A typical item display is shown in Figure 2.

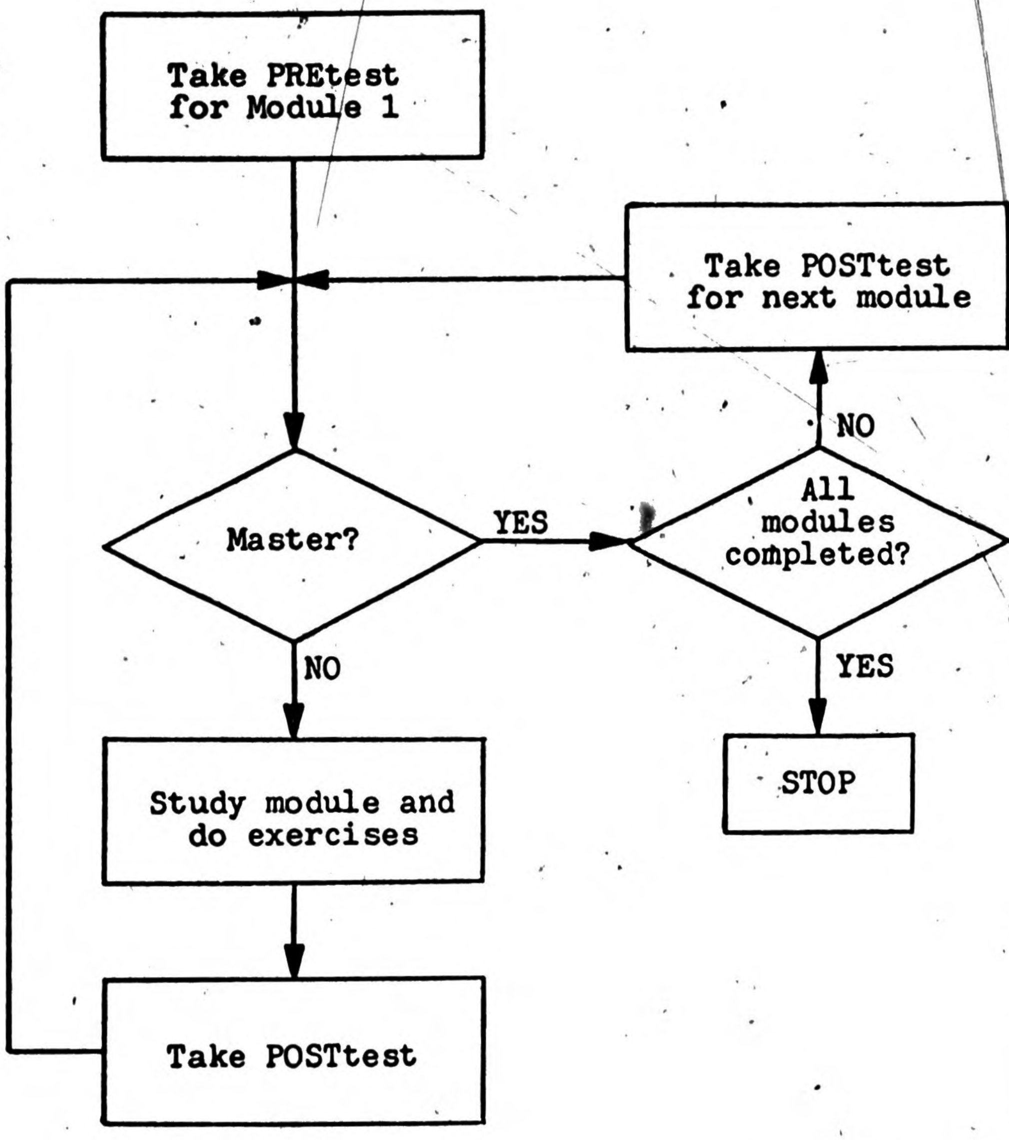

Figure 1

INTERACTION BETWEEN ON-LINE CMI SYSTEM AND OFF-LINE TUTORIAL DOCUMENTATION

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MULTIPLE CHOICE. Enter the letter of the alternative that BEST
answers the question or completes the sentence in the item below.

Enter SKIP if you don't know the answer (counted as incorrect).
Enter QUIT if you must terminate this test before it is completed.

Press the RETURN key after you type each entry.

10.  Which of the following statements will cause

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     to be displayed on the terminal?

        A.  PRINT "102 + 94"
        B.  PRINT 102 + 94
        C.  PRINT "102 + 94 = 102+94"
        D.  PRINT "102 + 94" = 102+94

     Your choice?
```

Figure 2

SAMPLE DISPLAY OF A MULTIPLE CHOICE ITEM
PRESENTED TO THE STUDENT

The system is highly human-engineered to make it as fool-proof as possible in a customer environment. For example, it provides the options "SKIP" and "QUIT" as shown in Figure 2, and it provides "error" messages in plain English: if the user enters "g" in response to a true/false item, the system will print, "Please enter only T, F, SKIP, or QUIT". It will then erase the user's previous response and make room for him or her to enter another one.

THE MASTERY DECISION MODEL

Sequential Testing

Even with a considerable Hawthorne Effect, customers still do not like to be tested. (There is always someone in every customer training course who will say, "I paid my money to be taught, not tested!") It is therefore important to keep the length of the module tests as short as possible. It is useless, however, to make these tests so short that their reliability approaches zero.

Since 1974, all courses developed by Digital's Educational Services Department have been developed using a criterion-referenced philosophy. This philosophy is especially applicable to industrial training, because we are interested in individual performance rather than a comparison between learners. We therefore required the CMI system to apply this philosophy as well. In 1975, this author reviewed the literature on criterion-referenced and computer-assisted testing, and the reader is referred to ERIC Document ED116633 for the complete text of that report.

The most highly developed criterion-referenced decision model that takes advantage of the capabilities of interactive computing is one developed by Richard Ferguson [1]. Ferguson's model is based on Wald's sequential probability test ratio [2]. This model allows two criterion scores to be defined, P0 and P1. Both of these scores are expressed in terms of percentages of correct responses. Learners whose scores are greater than P0 are classified as masters, and learners whose scores are less than P1 are classified as non-masters. Learners whose scores fall between P0 and P1 are presented with another item.

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[1] Ferguson, Richard L. Computer assistance for individualized measurement. Learning Resource and Development Center, University of Pittsburgh. March, 1971.

[2] Wald, Abraham. Sequential Anaylsis. John Wiley & Sons, Inc., New York, 1947.

This model also takes into account the probability with which the test developer is willing to allow Type I and Type II errors to occur [3]. For the purposes of the following discussion, let us define "A" as the probability with which we are willing to allow a Type I error to occur, and "B" as the probability with which we are willing to allow a Type II error to occur. The test developer can then assign values to P0, P1, A, and B to determine the learners' mastery state to any desired degree of accuracy.

Computations

After each test item is administered, the student's score, "S", is computed using the formula:

$$S = C \times \log(P1/P0) + W \times \log((1-P1)/(1-P0))$$

where "C" is the number of items answered correctly, and "W" is the number of items answered incorrectly.

If the student is a master,

$$S \leq \log(B/(1-A))$$

If the student is a non-master,

$$S \geq \log((1-B)/A)$$

If neither of these inequalities is true, i.e., if

$$\log(B/(1-A)) < S < \log((1-B)/A)$$

another test item is administered. The system continues in this manner until one of the first two inequalities is true or until 30 items have been administered. If no decision can be made after 30 items, the system classifies the student based on the differences between his or her score and the two criteria. The student is classified in the category whose criterion is closest to his or her computed score.

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[3] A Type I error is a false positive error and occurs when a true non-master is classified as a master by the test. A Type II error is a false negative error and occurs when a true master is classified as a non-master.

IMPLEMENTATION

Test Parameters

As mentioned previously, our CMI system generates both pretests and posttests. For this reason, it is important to realize that the seriousness of making Type I and Type II errors is different on pretests and posttests. If we make a Type I error on a pretest, we will be telling a student who has not studied that module to skip instruction that he or she really needs. This same error on a posttest is not as serious, because the student will have already studied the module at least once. A Type II error is never as serious as a Type I error, because this situation simply asks a student to repeat instruction that he or she does not really need.

To take the relative importance of these errors into consideration, our CMI system uses the parameters shown in Table 1 for the sequential testing decision model.

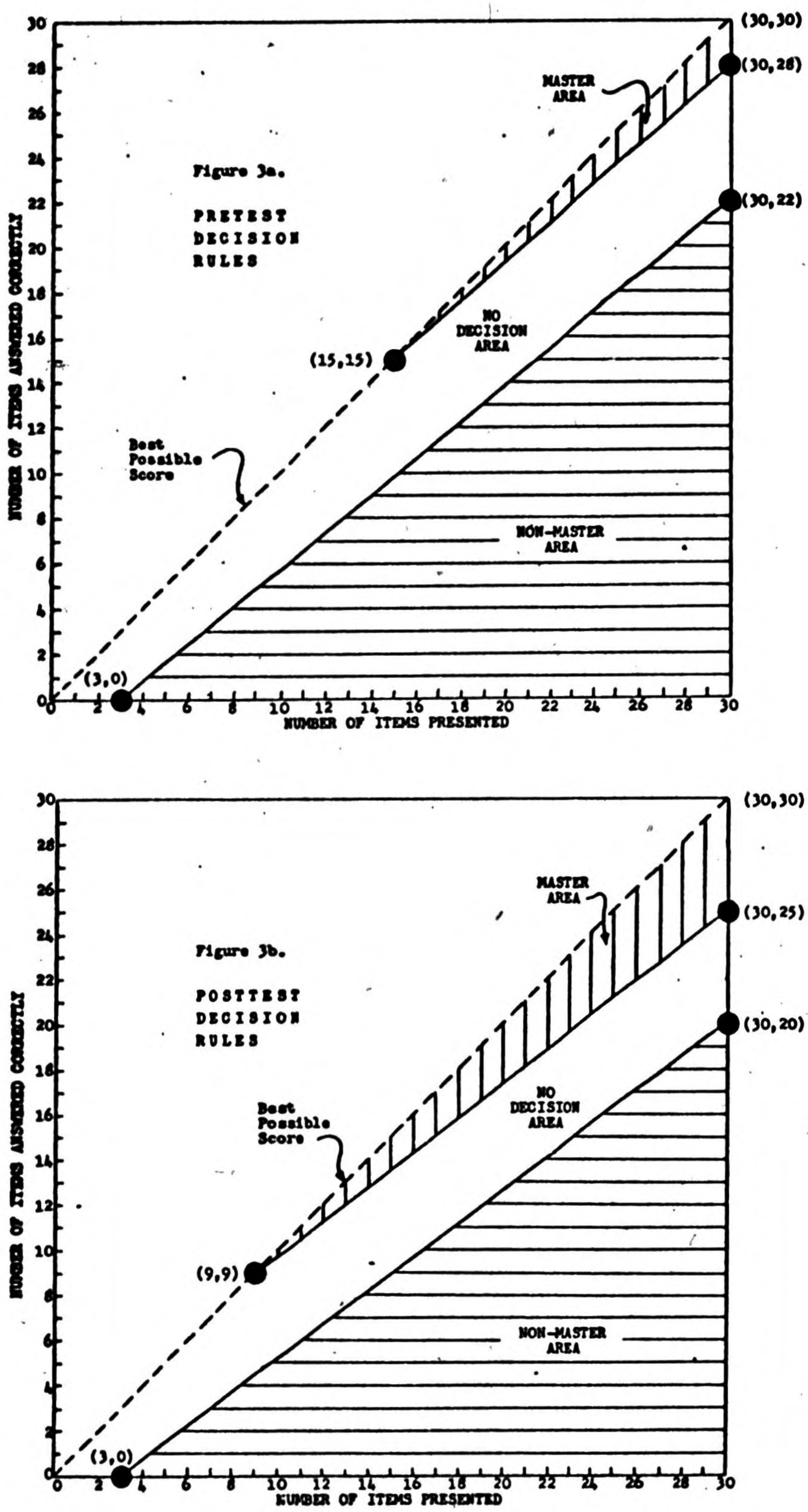
Table 1

SEQUENTIAL TESTING PARAMETERS FOR
PRETESTS AND POSTTESTS

Parameter	For PREtests	For POSTtests
Mastery Criterion ("P0")	0.90	0.85
Non-Mastery Criterion ("P1")	0.70	0.60
Allowable Probability of a Type I Error ("A")	0.025	0.050
Allowable Probability of a Type II Error ("B")	0.06	0.08

Notice that the allowable probability of a Type I error on a <u>post</u>test is twice as high as that on a <u>pre</u>test. To see how these parameters affect the mastery decision model in terms of raw scores, refer to Figures 3a and 3b.

Figure 3a shows a graph of the pretest decision rules, while Figure 3b shows a graph of the posttest decision rules. Note the difference in the sizes of the two master areas and the specific points that are labelled. The point labelled "(3,0)" in both graphs indicates that the earliest that a <u>non-master</u> decision could be made on either test is



Figures 3a and 3b

GRAPHS OF THE PRETEST AND POSTTEST DECISION RULES

after 3 items have been presented. If, at this time, the student has not answered any items correctly, he or she is classified as a non-master.

In Figure 3a, the point labelled "(15,15)" indicates that the earliest that a master decision could be made on a pretest is after 15 items have been presented and all 15 have been answered correctly. Contrast this point with the one labelled "(9,9)" in Figure 3b. The latter indicates that the earliest that a master decision could be made on a posttest is after 9 items have been presented and answered correctly. Therefore, the posttest mastery criterion is less stringent than the pretest mastery criterion. This is exactly what we wanted, because we have already shown that an erroneous master decision on a posttest is less serious than the corresponding error on a pretest [4].

Closing the Feedback Loop

The system on which these CMI programs are currently implemented is a diskette-based system. The complete CMI system will be supplied to users on a diskette even when they purchase the minimum configuration. After they complete all of the modules in the course, users will be instructed to mail their diskettes back to Digital in special business reply envelopes that will also be supplied. We will read their data, zero the log files if so requested, and return the diskettes. The data stored by the programs will allow us to do complete criterion-referenced item analysis on the users' responses and check the status of the users on each module. Users who complete the entire course will receive a diploma when their diskettes are returned.

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[4] The actual decision model implemented on our CMI system is slightly more complex than the one discussed here, because Wald's sequential probability test ratio was developed for events that occur with equal probabilities. Since the probability of getting a true/false item correct by guessing is different from that for a multiple choice item, our system computes a weighting factor to correct for the difference between our application of Wald's formulas and the probability model for which they were originally developed.

FUTURE ENHANCEMENTS

All of the programs that make up this CMI system are written in the BASIC language. This makes them highly transportable to almost all of Digital's operating systems, and we plan to use them for most of our tutorial documentation projects in the future. In addition, all of the CMI programs and data files for about 800 test items will fit on a single, dual-density diskette (approximately 250K PDP-11 words).

These characteristics make the CMI system applicable to internal and large systems training as well as small systems training, because it is small enough to fit on a diskette yet sophisticated enough to handle more and larger item banks if additional disk space is available.

We hope to begin putting appropriate parts of the actual instruction on-line on our small systems in the near future to complement the testing and course management functions that we have available today.